

ACCELERATED LIFE TESTING EFFECTS ON CMOS MICROCIRCUIT CHARACTERISTICS

Phase II Report
Interim

January 1977 to July 1977

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Prepared By
RCA, SOLID STATE DIVISION
Somerville, New Jersey

Prepared for
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ABSTRACT

This report describes the work performed under NASA contract NAS8-31905 by the RCA Solid State Division, Somerville, N.J. facility and the integrated-circuits manufacturing facility in Findlay, Ohio. This report covers Phase II of the contract and the time period from Jan. 1977 to July 1977.

In order for the results from Phase I (250°C) and from Phase II (200°C) to be meaningful, data generated from Phase III (125°C) must be considered. This data, although preliminary, is included in this report. Subsequent reports will tie the data from all three phases of this contract together so that meaningful analyses and recommendations can be made.

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SECTION I

INTRODUCTION

The need for a practical short-term test program, the results of which can be meaningfully interpreted to predict the long-term reliability of CMOS microcircuits, has been recognized. Many months if not years are required to run a life test under conditions reflecting actual applications and requirements of Class A devices. The impracticality of such a test led to the reliance by the industry on long-term reliability predictions based on interpolations of results gathered from accelerated life tests. It is essential to run long (thousands of hours) 125°C life tests to confirm experimentally the validity of such interpolations for CMOS devices. There is a definite possibility that accelerated tests cause the temperature thresholds of a device to be exceeded, thus triggering failure mechanisms unrelated to a device's operation within its specified ratings. The somewhat arbitrary limits established for the use of accelerated life tests must be either experimentally confirmed or revised in accordance with experimental data. The varying complexity of present day CMOS devices should be recognized as a factor in reliability predictions.

The purpose of this program is to determine the consistency of the CMOS microcircuit activation energy between the range of 125°C to 200°C and the range of 200°C to 250°C. Also, this program will determine the relationship of accelerated life-test failures to rated temperature operation and develop a test specification for accelerated life tests within the scope of the M38510 specifications.

SECTION I
INTRODUCTION (cont'd)

The program encompasses three phases. Phase I is the 250°C accelerated life test, Phase II is the 200°C accelerated life test, and Phase III is the 125°C accelerated life test. This report deals with Phase II.

SECTION II

OBJECTIVE

The objective of Phase II of this program is:

1. To conduct an accelerated life test of sufficient duration to generate a minimum of 50% cumulative failures in each lot of devices. This data coupled with data generated in Phase I and Phase III should provide a basis for determining the consistency of the activation energy among the three temperatures (250°C, 200°C and 125°C).
2. To provide a basis for recommendations of conditions and limits to be used as part of a microcircuits qualification procedure.
3. To determine whether any thresholds are exceeded during the high temperature testing, which could trigger failure mechanisms unique to that temperature.
4. To provide additional test data for the determination of the usefulness of the 250°C accelerated test as a predictor of long-term reliability.

SECTION III

DEVICE SELECTION

The choice of microcircuit devices for this program was made according to the following criteria:

1. High-reliability Class A devices.
2. Varying degree of complexity representing the product line.
3. Availability.

The following microcircuit types were chosen for this program:

<u>MIL DESIGNATIONS</u>	<u>GENERIC NAMES</u>	<u>FUNCTION</u>
M38510/05001ADX	CD4011A	Two-input quadruple logic gate
M38510/05101ADX	CD4013A	"D"-type flip flop
M38510/05605ADX	CD4024A	Seven-stage binary counter.

Table I summarizes various complexity factors for these devices:

Table I - Varying Complexity of Devices

<u>Type</u>	<u>Si Area</u>	<u>No. of Active Elements</u>	<u>No. of Inputs</u>	<u>No. of Outputs</u>
CD4011A	1.9 mm ²	13	8	4
CD4013A	2.1 mm ²	64	8	4
CD4024A	4.2 mm ²	134	2	7

The devices are in flat packs with weldable leads. Solder-dipped leads could not be used at temperatures above the solder melting point. These devices were tested to the individual M38510/50 specifications. Table III of these specifications specifies the electrical parameters' test

SECTION III
DEVICE SELECTION (cont'd)

conditions and limits for the Group A testing for individual microcircuits. Subgroups 1, 2, 3, 7, and 8 were performed at each measurement point throughout the test program and are the basis for the consequent data analysis.

SECTION IV

TEST VOLTAGE AND BIAS

The choice of bias was dictated by the desire to further accelerate the life testing process by stressing the n-channel transistor to possibly the worst-case condition. The available evidence suggests that the n-channel transistor in CMOS microcircuits is the weak link when biased to the off condition (gate is low with respect to drain). The drain-to-source and drain-to-gate potentials set up under this bias accelerate movement of the positively charged (usually sodium) particles. These particles are thought to accumulate in the oxide, thereby neutralizing the effect of the negatively biased gate and setting up a mechanism for potential leakage. The biases used are shown in the pin connection diagrams of Fig. 1. The operating voltage was chosen as 12.5 volts dc to conform to the M-38510 specifications.

SECTION V

THE TEST

The test matrix was developed and is shown in Fig. 2. Devices were selected from three lots in each type to represent broad process variations. The program encompasses 3 life-test temperatures. Each lot is represented by 20 test devices in each life test for a total of 60 test devices of each type. Each test sample of 20 test devices had, in addition, 5 control devices which were monitored at each measurement point together with the test devices, but were not life tested.

Prior to beginning of the contract, trial runs were started. Data from those runs prompted the introduction of more measurement points for the 250°C as well as the 200°C life test. The testing at each measurement point was broadened to include 125°C, and -55°C measurements.

As the final results of the 250°C test become available and the first results of the 200°C tests started to come in a desirability to evaluate the impact of the manufacturing environment upon the test results was recognized. In order to accomplish this, the high temperature burn-in ovens upon the completion of the 200°C test were transferred from Findlay, Ohio plant to Somerville, N.J. There were devices left over from some of the lots made for this program. These devices were used to run repeat tests. Two device types: CD4011A and CD4013A were tested at 250°C and 200°C. The task was accomplished by the engineering personnel and the measurement at down periods were done utilizing Somerville's facilities. These tests were completed at no additional cost to the government.

SECTION VI

TEST DATA

Attributes

The summaries of the failure attributes and the cumulative percentage of failures are presented in table form. The 200°C test results are shown in Tables II, III & IV. The results of the 250°C and the 200°C repeat tests are shown in Tables V, VI, VII and VIII. The sample size does not always remain 20 devices because those devices that were lost due to malfunctioning of the automated test equipment and those which were continuity rejects because of poor socket connections were removed from the count. The data from these tables were then plotted on the log normal graph paper to present the cumulative percent of failures versus the test time. The resultant curves from the basic tests and the repeat test are superimposed to demonstrate the repeatability of results of test conducted under different environment. Refer to Figs. 3, 4, and 5.

Activation Energy

The resultant curves resemble the shape of S curves previously reported in other studies of accelerated tests. Only the upper portions of the S shape are remaining. The lower portions (freak distributions) have been largely removed by the burn-ins. The region to the right of the dashed line on each graph represents the main distribution and is of special interest in predicting the long-term reliability of the devices. This region has increasing failure rates which can be readily verified on the Weibull distribution plots.

TEST DATA

Activation Energy (cont'd)

The activation energy between 250°C and 200°C is determined on the basis of main distributions. The values of activation energy for each device type are tabulated in Table IX. These values were determined on the basis of two points; MTTF at 250°C and 200°C. The activation energy varies from device type to device type.

The Effect of Temperature

The region to the left of the dotted line, is an indicator of the effectiveness of burn-in rather than that of the inherent reliability of the devices. Ideally these regions should have no failures with an effective burn-in schedule. Since the burn-in temperature for the devices in this program is 125°C, the percent of freak failures increases correspondingly at 200°C and 250°C indicating lesser effectiveness of the 125°C burn-in for the devices to be tested at those temperatures. The 125°C test cell is expected to produce additional supporting evidence by having least number of freak failures. This trend is especially evident in Fig. 3 and Fig. 4. This greater number of freak failures at 200°C and 250°C may be an indication of an exceeded temperature threshold. Therefore, care must be exercised in developing acceptance criteria for an accelerated test so as not to let the emerging freak distribution interfere with the interpretation of the test results.

TEST DATA

Device Complexity

The test results indicate that the mean time to failure depends upon the complexity of a device when criticized to MIL-M-38510 electrical end points. Of all the factors listed in Table I the number of active devices on a chip most closely correlated to the mean time to failure. The curve of Fig. 6 demonstrates that relationship for the 250°C test cell. It should be pointed out that this plot is merely an illustration and not a result of rigorous analysis of this relationship. A similar relationship can be derived for 200°C from the same graphs. This illustration presents sufficient evidence against making generalizations when devising acceptance criteria for life tests; generalizations based on one technology and applied to another or based on test results of one device type and applied to all device types within the same technology.

Cost Considerations

In the production environment efficiency and trouble free operations are extremely important. This study uncovered two problem areas which were the consequence of the high temperature material used for sockets on the life test panels and for the device carriers. The material aromatic copolyester

TEST DATA
Cost Considerations

is extremely brittle. Constant breakage of the life test sockets necessitated costly repairs and resulted in delays upsetting test schedules. Breakage of very fragile clips that hold devices in carriers resulted in delays in testing as well as in the automated measurements. It was also found that the carriers warp under exposure to 250°C. The warped carrier created pin contact problems in test sockets of the automated measuring equipment. Good devices were rejected as continuity failures. These rejects had to be verified by other means of testing with the resultant loss of time. All these factors contributed significantly to the cost of running the accelerated test. An assessment of the relative cost of running accelerated life tests was made and is presented in Table X. All costs are normalized to 125°C for easy comparison.

SECTION VII

FAILURE ANALYSIS

CD4011A - The most prevalent type of failure is the loaded output voltage followed closely by the input leakage (Ii). These two most common types of failure depending upon the severity (amount of deviation from the norm) may result in an eventual functional failure.

CD4013A - The most prevalent types of failure are the total leakage (Iss) and the input leakage (Ii). Again depending upon the severity of the leakage it may eventually result in a functional failure. The ten Iss tests specified by the MIL-M-38510 detail specification representing different states of the flip-flop do not appear as failures with the same frequency. States which have clock input "high" exhibit more frequent Iss failures than do other states. The "D" input tends to have more frequent than other inputs Ii failures.

CD4024A - The most prevalent type of failure is the total leakage (Iss). All nine Iss tests except one show equal frequency of occurrence. The ninth test (input and reset are high) exhibits considerable lower frequency of occurrence,

Improvement with the Bake

All failures from the 250°C were subjected to a 200°C, 24 hr stabilizing bake. The large percentage of the failures showed improvement and some recovered completely. The results of this bake are tabulated in Table XI,

FAILURE ANALYSIS
Improvement with the Bake

These post bake results are the first indications that the instability of the CMOS microcircuits tested under the high temperature accelerated conditions are possibly caused by the presence of mobile ions.

Gas Analysis

Prior to gas analysis all test devices were subjected to hermeticity test. All devices were found hermetic. Twelve devices (4 from each device type) were subjected to gas analysis. The devices were chosen to represent typical failures within each device type. Devices which did not fail were also included. The analysis on these 12 devices was performed by RCA Methods and Materials Laboratory. The summary of this analysis is given in Table XII. This table indicates the type of failure for each device: Iss - total leakage, Ii - input leakage, F - functional failure, Vth - threshold failure. Although the threshold voltage is not identified as a test parameter by the MIL-M-38510 specifications, it was routinely measured at all measurement points. The threshold tests are included in the table as indicators of device stability under the accelerated testing, but are not considered as one of the criteria for failures. Devices which did not fail are identified with "good". The table further identifies devices which recovered after the bake with R, those which improved with I, and those that did not improve with NI. The constituent analysis is given in percent by volume unless otherwise indicated. In addition to the listed constituents, small amounts (not exceeding 500 ppm) of other organic compounds were found.

FAILURE ANALYSIS
Gas Analysis

Twelve additional devices (4 from each device type) were made available to Rome Air Development Center upon request by NASA for the gas analysis to be performed by RADC. The summary of RADC findings is tabulated in Table XIII. The complete RADC report is attached in the Appendix. The summary table has only two constituents shown (H_2O and CO_2) which appear to be the two most significant indicators. It can be seen that only those devices which were on the accelerated tests display considerable increase in the amount of H_2O and CO_2 . The amount of water vapor roughly correlates (inversely) to time to failure. The CD4011A failures at the indicated time (64 and 32 hrs) were small increases of input leakage. Multiple failures were recorded at 120 hrs. The CD4024A (Nos. 42 and 30) although had high water vapor content did not fail at 32 hours, for that reason the time is indicated in parenthesis, but the test on the entire lot was discontinued having accumulated at least 50% of failed devices.

It should be noted that there is significant difference in the amount of moisture indicated by the two gas analyses; one performed by RCA and the other by RADC. These variations are attributed to the differences in measurement techniques. RCA measurements are instantaneously done at room temperature: RADC measurements use integration techniques and are conducted at $100^{\circ}C$.

FAILURE ANALYSIS
Chip Analysis

Chip Analysis

Representative failures from all three device types were opened and failure analysis performed. This analysis was aimed at determining the possible cause for the failures. The summary of this analysis is given in Tables XIV - XVII. The tables identify the devices, failure indicators, pins at which problems were detected, and the failure mechanisms.

SECTION VIII

CONCLUSIONS

On the basis of the completed work the following conclusions can be reached:

1. Different activation energies between 250°C and 200°C were determined for the three tested device types. CD4011A had the highest activation energy and the CD4024A had the lowest activation energy.
2. Two factors seem to have influenced time to failure of tested CMOS devices: a) The complexity factor and b) The amount of moisture detected inside of the devices after the test.
3. Surface instability is the important factor which seems to have caused most of the failures.
4. Test facilities at 250°C are costly to maintain.

SECTION IX

ACKNOWLEDGEMENT

Acknowledgement is given Mr. E. Reiss for his guidance in this project, to Messrs. L. Campbell and F. Gusler for developing and implementing the computer test programs to Mr. H. Ahlers who had the difficult task of running an engineering program in a production environment, to Mr. C. Petrizio and members of the Design Automation activity for their efforts in computer data analysis, and to members of the Reliability Engineering Laboratory for their help in failure analysis.

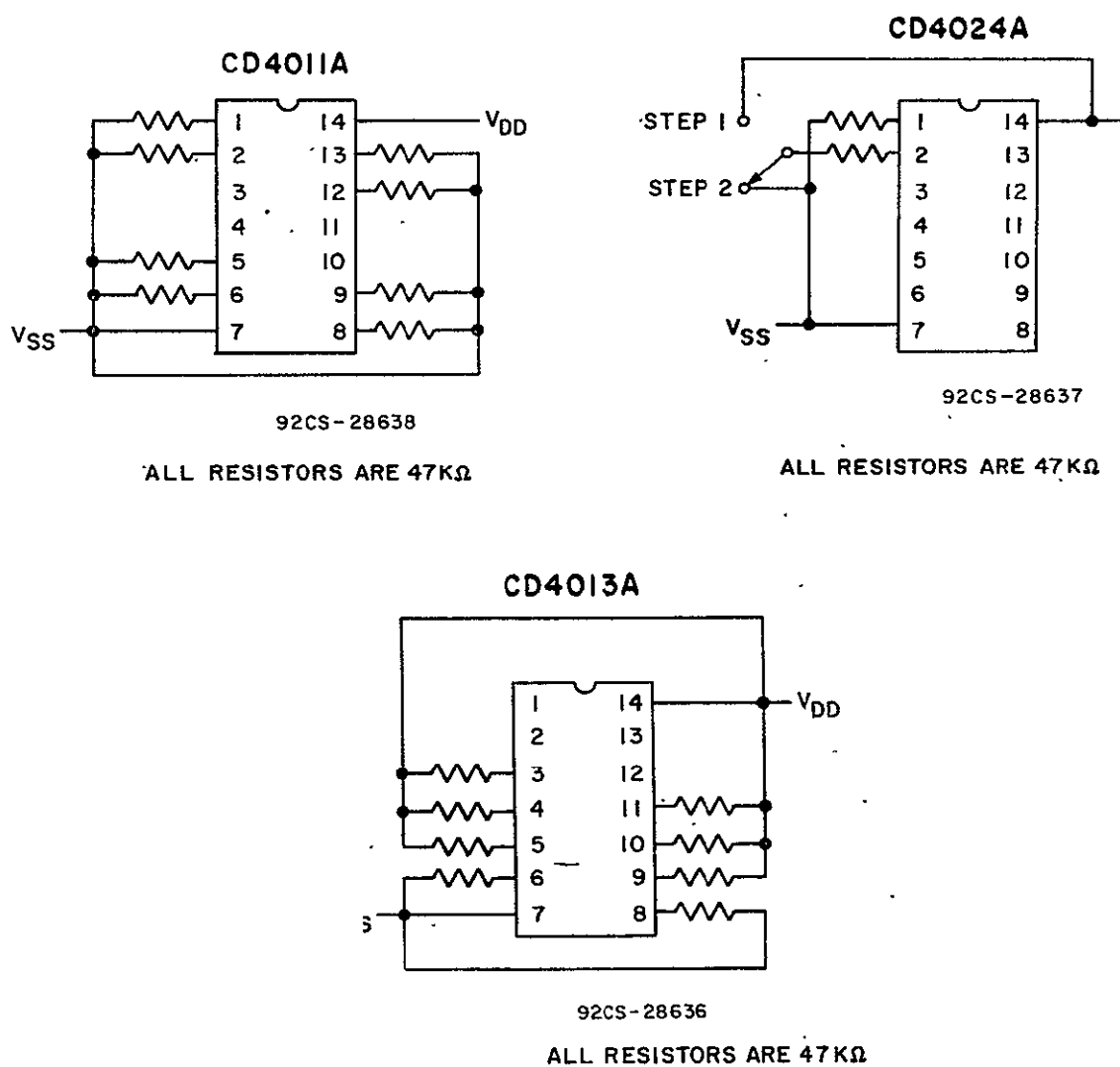


Fig. 1 - Bias connection diagrams.

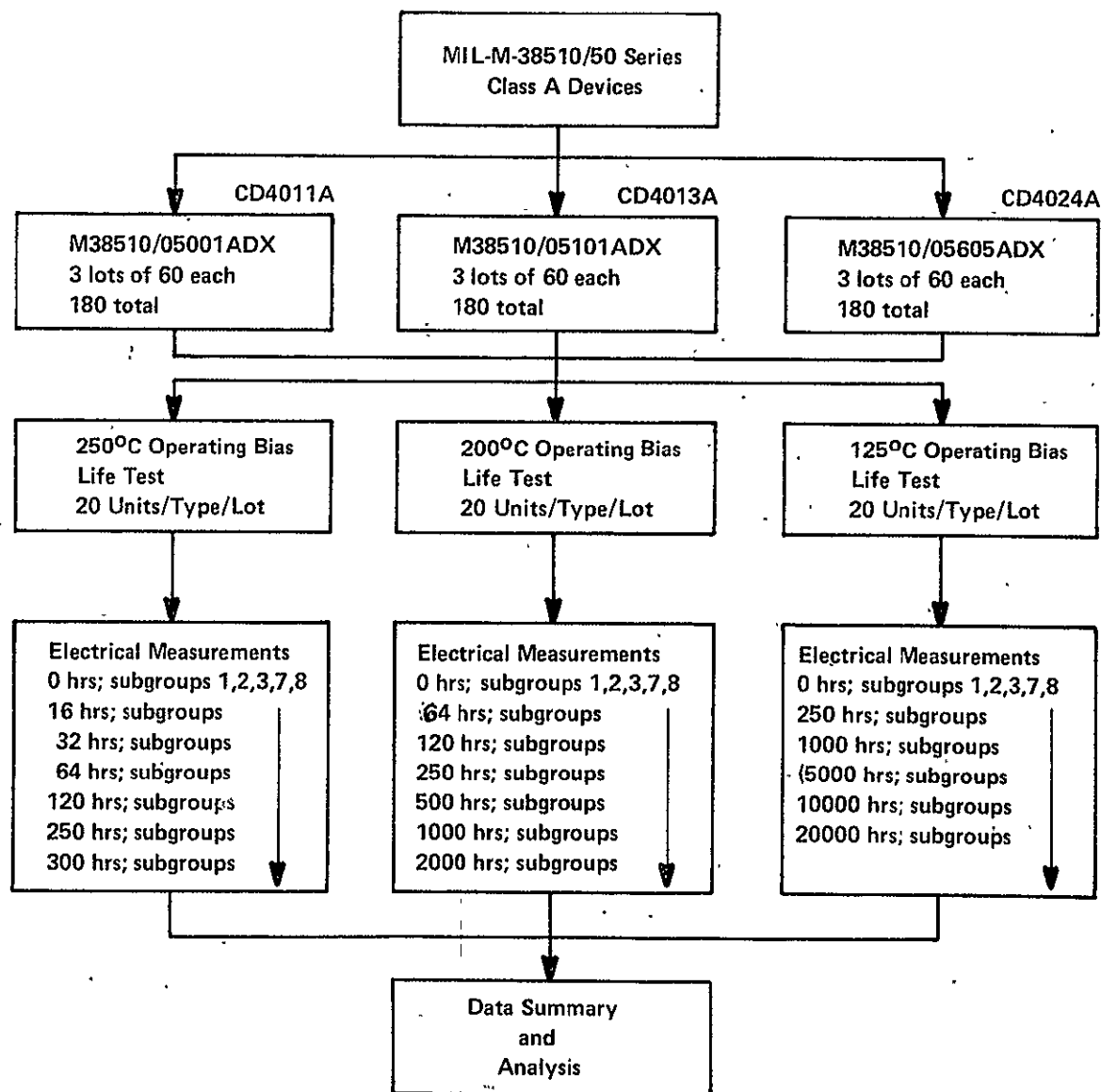


Fig. 2 - Test Matrix

TABLE II

200°C Test

Type CD4011A Summary of Failure Attributes

Hours Lot No.	64	120	250	500	1000	1500	2000	
5361743	0/20	0/20	0/20	0/20	0/20	6/16	11/18	
6153053	1/19	1/19	1/19	2/19	4/19	4/19	14/17	
6153063	1/19	1/18	1/18	1/18		6/18	5/17	
3-Lot Total	2/58	2/57	2/57	3/57		16/55	30/52	
3-Lot % Failure	3.4	3.5	3.5	3.5		29	58	

TABLE III

200°C Test

Type CD4013A Summary of Failure Attributes

Hours Lot No.	64	120	250	500	1000			
6153083	0/19	1/17	1/16	3/16	16/16			
6123243	0/20	0/18	0/19	0/19	17/19			
2-Lot Total	0/39	1/35	1/35	3/35	33/35			
2-Lot % Failure	0	2.8	2.8	8.5	94			

TABLE IV

200°C Test

Type CD4024A Summary of Failure Attributes

Hours Lot No.	64	120	250	500				
6201053	0/20	3/20	11/19	17/19				
6202233	0/20	1/20	7/20	17/19				
6201063	3/20	3/20	11/20	20/20				
3-Lot Total	3/60	7/60	29/59	56/58				
3-Lot % Failure	5	12	49	95				

TABLE V

250°C Repeat		CD4011A						
Hours		16	32	64	96	128		
Lot No.								
5361740	3-Lot							
6153050	Total	1/38	1/38	3/38	3/38	15/38		
6153060								
3-Lot % Failure		2.6	2.6	7.9	7.9	39.5		

TABLE VI

250°C Repeat		CD4013A Summary of Failure Attributes						
Hours		18	16	32	48	64	80	
Lot No.								
6153080	2-Lot							
6123240	Total	2/38	3/38	5/38	8/38	24/38		
2-Lot % Failure		5.3	7.9	13	21	63		

TABLE VII

200°C Repeat		Type CD4011A Summary of Failure Attributes							
Hours		64	128	250	500	1000	1500	2000	2500
Lot No.									
5361740									
6153050	3-Lot	0/38	3/38	4/38	4/38	6/38	7/38	11/38	30/38
6153060	Total								
3-Lot	% Failure	0	8	11	11	16	18	29	79

TABLE VIII

200°C Repeat		Type CD4013A Summary of Failure Attributes							
Hours		64	128	250	500	1000	1500	2000	2500
Lot No.									
6123240		2/38	2/38	2/38	3/38	9/38	19/38	37/38	
% Failure		5	5	5	8	23	50	97	

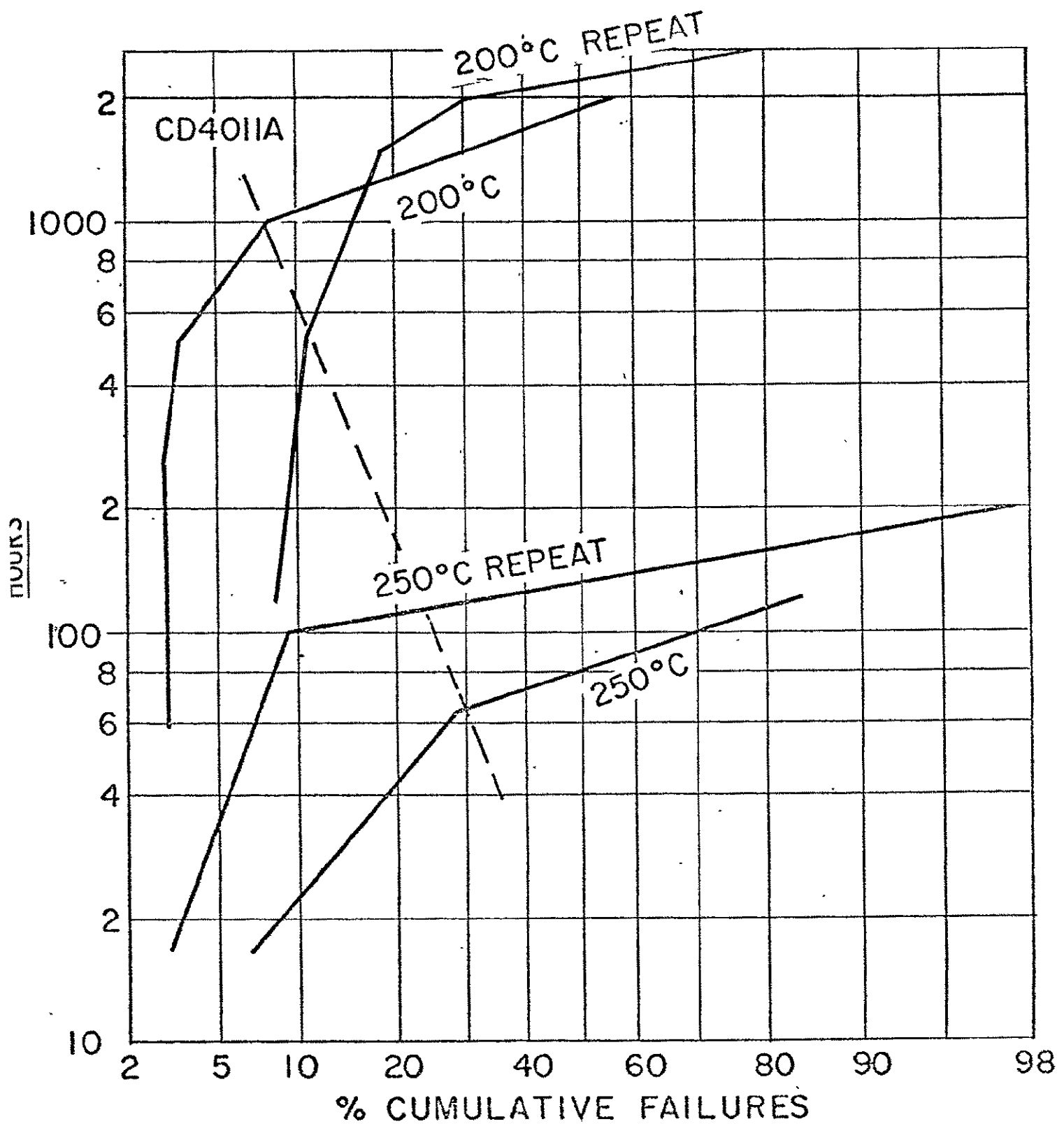


Fig. 3 - Test Results for the CD4011A

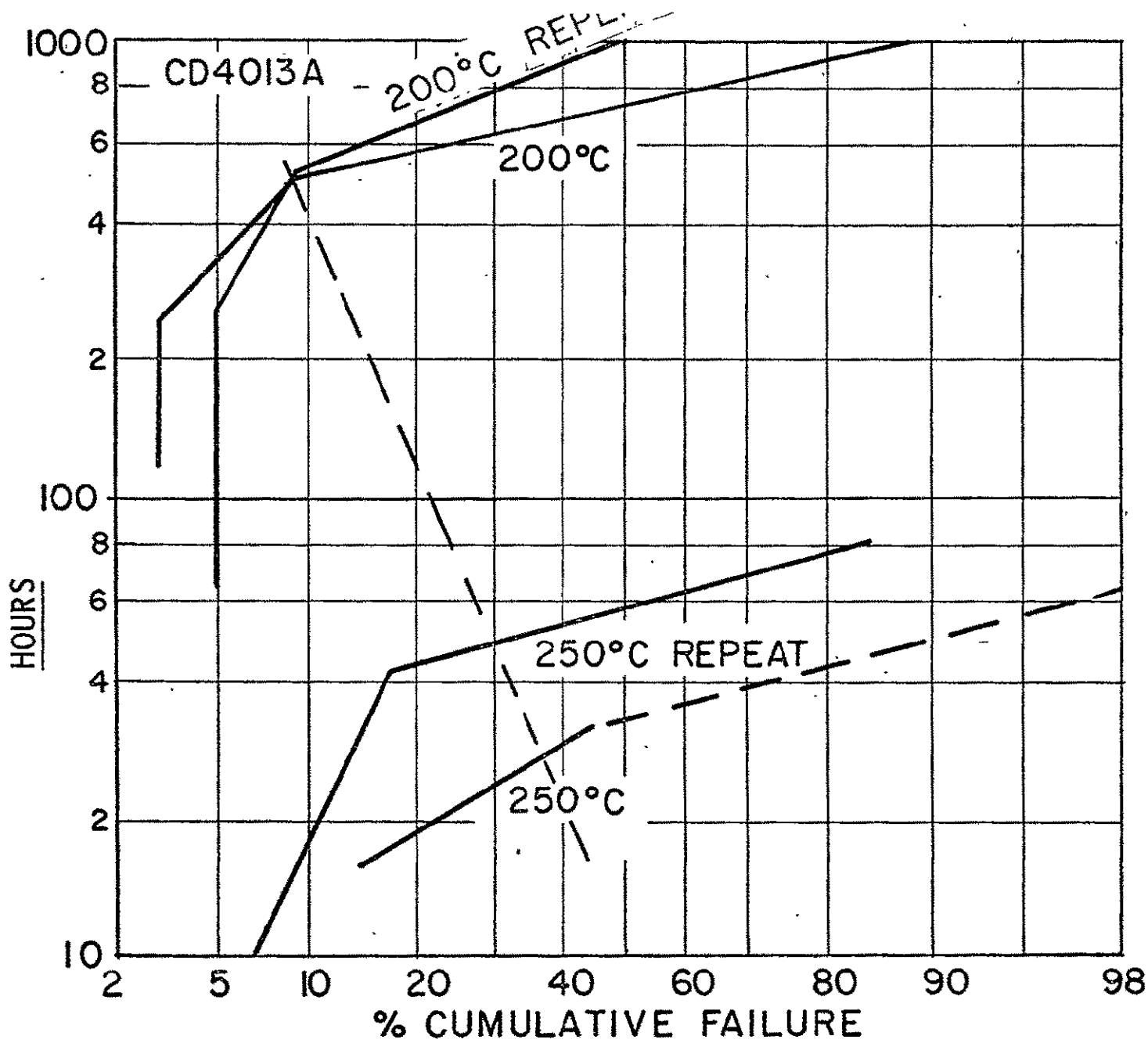


Fig. 4 - Test Results for the CD4013A

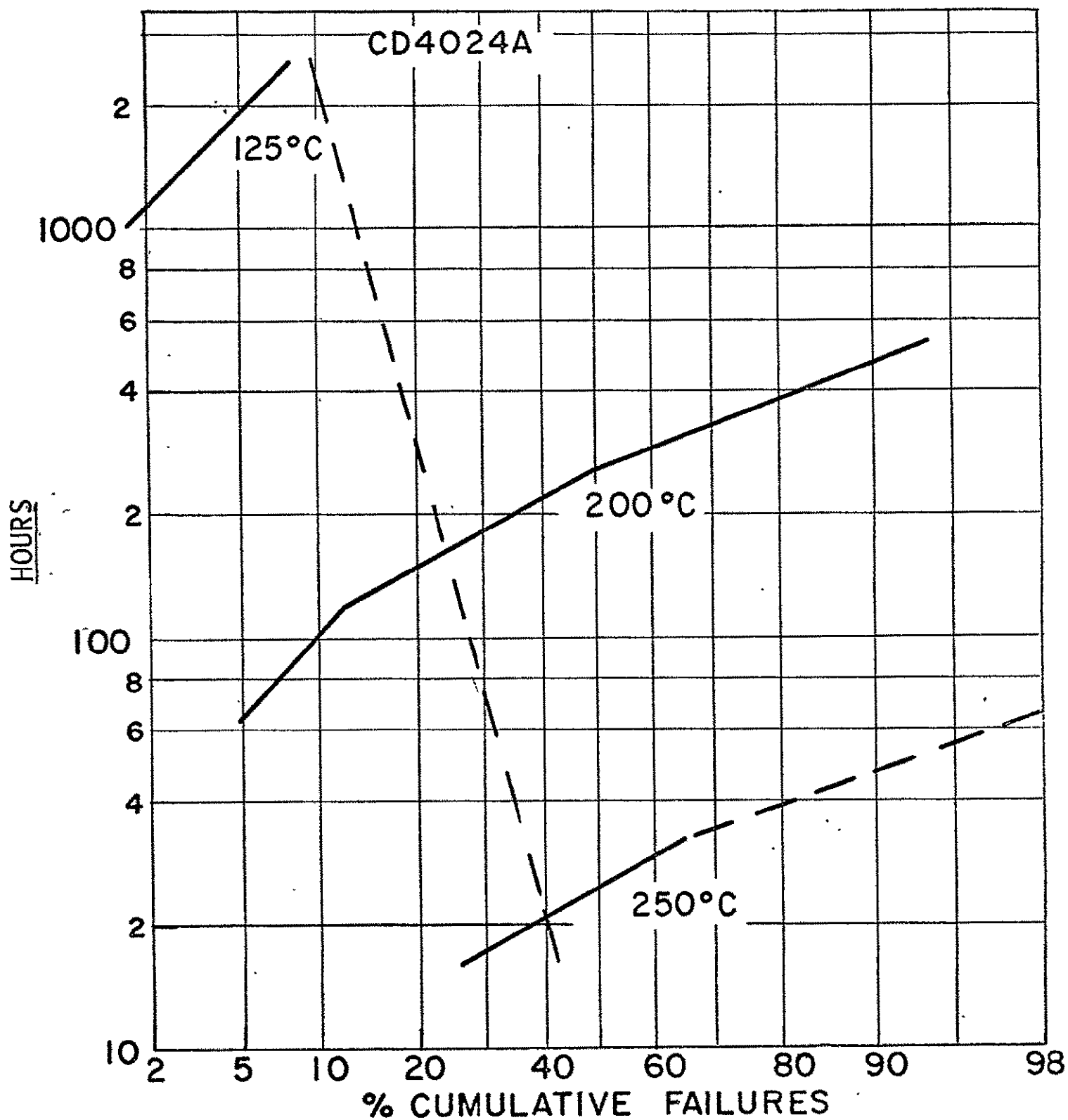


Fig. 5 - Test Results for the CD4024A

TABLE IX

ACTIVATION ENERGY

Main Distribution

<u>Type</u>	<u>Activation Energy</u> <u>200°C - 250°C</u>
CD4011A	1.4 eV
CD4013A	1.1 eV
CD4024A	1.0 eV

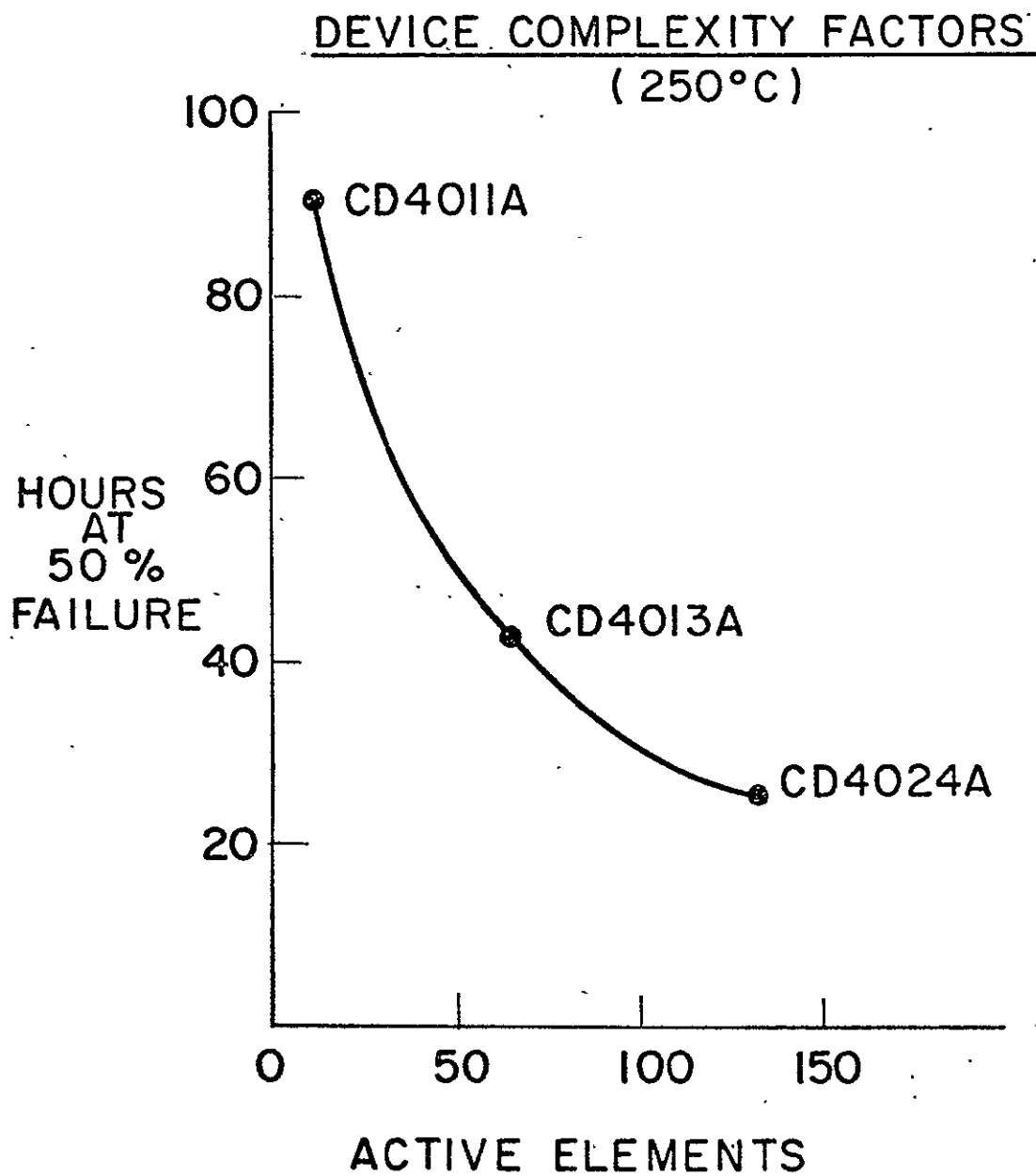


Fig. 6 - Device Complexity Factors (250°C)

TABLE X

RELATIVE COSTSHigh Temperature Facilities

<u>Factors</u>	<u>Temperature</u>		
	<u>125° C</u>	<u>200° C</u>	<u>250° C</u>
Oven Cost	1	1	1.25
Socket Cost	1	2	7.5
Socket Life	1	1	2.5
Oven Life	1	2	2
Maintenance	1	1.25	1.5
Total	1	5	70

TABLE XI

SUMMARY OF POST BAKE RESULTS

250°C Life Test
 200°C 24 Hr Bake

<u>Type/Lot</u>	<u>Hrs. L.T.</u>	<u>No. of Failures</u>	<u>Post Bake</u>		<u>Recovered</u>	
			<u>Improved Amt</u>	<u>%</u>	<u>Amt</u>	<u>%</u>
CD4011A						
5361740	120	17	5	30	10	59
6153050	120	18	8	44	8	44
CD4013A						
5393021	32	11	3	27	7	64
6153081	64	19	8	42	7	37
6123241	32	10	1	10	8	80
CD4024A						
6201061	32	15	8	53	3	20
6202232	64	18	15	83	1	6
6201051	32	11	3	27	1	9

TABLE XII - Summary of Gas Analysis (RCA)

Device Type	CD4011A				CD4013A				CD4024A			
Device Number	4	29	33	56	42	88	10	77	33	62	58	4
Type of Failure	Iss	Iss, V _{th}	Good	Good	Iss	Iss, Ii F, V _{th}	Ii	Ii	Iss, Ii	Iss	Good	Iss
Post Bake Result	R	I	-	-	I	I	R	R	NT	NT	-	I
Constituent												
H ₂	.15	-	.1	.17	.2	.11	-	.038	830 ppm	.12	.61	.08
He	-	-	-	-	-	-	-	-	-	-	-	-
H ₂ O	1.2	.15	.33	.06	.29	.47	-	-	.46	.34	.42	3.34
N ₂	96.8	91.5	93.5	89.1	88.8	88.0	93.9	90.5	80.9	82.1	83.46	74.79
O ₂	.16	.26	.32	.15	.22	.17	.18	.15	.17	.10	.1	.36
Ar	-	-	.05	-	-	-	-	-	370 ppm	150 ppm	.37	.09
CO ₂	.29	7.6	5.05	9.16	9.8	10.6	5.6	8.77	16.8	15.9	14.33	20.06
Propane	.82	.16	-	-	.26	.29	-	-	.67	.58	-	-
Acetone	-	.23	-	-	.31	.21	.44	.15	490 ppm	.42	.42	.38
Ethanol.	750 ppm	.12	-	-	.15	.12	890 ppm	.4	680 ppm	660 ppm	.06	.08
Acetylene	.47	-	-	-	-	-	-	-	.32	.27	-	-

TABLE XIII - Summary of Gas Analysis (RADC)

Device Type	CD4011A				CD4013A				CD4024A			
Device Number	49	50	39	41	23	24	94	95	42	30	19	20
Failure Indicator	C	C	Ii	Ii	C	C	Iss,Vo F	Iss F,V _{th}	Good	Good	Iss	Iss,Ii Vo
Time to Failure, Hrs.	-	-	64	32	-	-	64	16	(32)	(32)	32	64
Constituent Post Bake Result	-	-	I	I	-	-	I	NI	-	-	I	NI
Water Vapor (%)	.1	.1	7.8	5.9	-	.1	4.5	12.2	12.2	12.0	16.8	11.8
Carbon Dioxide (%)	.3	.3	7.9	7.2	.6	.4	6.3	10.9	7.7	6.0	9.7	7.1

C = Control Devices

TABLE XIV

250°C Test

CD4011A Failure Analysis

Lot No. Device No.	Failure Indicator	Failure Mechanism and/or Cause
5361740 18	Iss, V, Lkg P4,7,10,11 ^	P10 drain to source N channel - minor ionic contamination.
6153050 28	Iss, V, P13-P14 short Lkg P3,4,7,10,11 - P2,6, 9,13 bias high	P13 - VDD diode shorted. SEM shows cracks at breakdown site. Electrical overstress.
6153050 36	Iss, V, Lkg P3,4,7,10	P channel MOS of P3,4,11 had inversion leakage in 50-100 nanoamp range; baking @ 200 did not improve. Etching oxide cleared leakage. Mobile ion contamination.
6153060 53, 54, 55	Pin 7 open	Vss metal run burned open. Latch during life.

TABLE XV

250°C Test

CD4013A Failure Analysis

Lot No. Device No.	Failure Indicator	Failure Mechanism and/or Cause
6123241 7	Iss, Lkg 7,8,9	Leakage on P9 transmission gate to VDD = 100mA cleared with oxide etch. Mobile ion contamination.
6153001 89		Unit in carrier backwards.
6153001 90	Iss, I_H V, Pth, Lkg. Pl, 2,7,12,13	Heavy invers. - 5uA +, V_{DD} to Vss diodes cleared with aluminum etch, probably inversion where metal run was over oxide.

TABLE XVI

250°C Test

CD4024A Failure Analysis

Lot No. Device No.	Failure Indicator	Failure Mechanisms and/or Cause
6202232 2	Iss, V, P _{TH} P14 Lkg. P3 Lkg with clock low = 130uA high = 10uA	P3 - V _{DD} diode. Leakage cleared with Al etch. P3 N&P MOS source to drain. Leakage cleared with Al etch + 200°C bake 16 hr. Mobile ion contamination.
6202232 11	Iss, V, P _{TH} Leakage P7, 14. P3 lkg. during toggle switch	Vss to V _{DD} diode 1uA inversion leakage + 4V breakdown. Bake increased inversion to 2.5uA. Leakage cleared with oxide etch, Mobile ion contamination.
6201061 26	Iss, I _I , P14 - Low Break- down, 1.8V, P4, P5 Lkg during 10V pulse test.	P5, drain to source, N channel 10uA @ 20V cleared with bake. Mobile ion contamination.
6201061 27	Iss, Pulse test. P1 - I _{DD} = 2.4mA	P1 and P2 P channel source to drain = 20uA. Inversion leakage cleared with 200°C bake. Mobile ion contamination
6201051 51	Iss, V, P _{TH} , Lkg P7, P14	Carrier insert had melted. Failure analysis halted.

200°C Test

CD4013A Failure Analysis

Lot No. Device No.	Failure Indicator	Failure Mechanism and/or Cause
5393023 334	Cont. fail. P1,P2 - Short. P7 Open, P12,P13 - Short.	Multiple sites of large localized current between P2 and P12. Drains + Vss. Vss metal run burned open. Cause: Electrical overstress during life.
5393023 335	Same as 334	Same as 334
5393023 336	P2, P12 short. P7 Open	Same as 334

APPENDIX

Gas Analysis by RADC

03-02-77

RCA CD4011 S/N 39

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CONSTITUENT	CONCENTRATION, %(V/V)
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HYDROGEN	.1
METHANE	.5
WATER VAPOR	7.8
NITROGEN	83.5
OXYGEN	.1
CARBON DIOXIDE	7.9

14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

=====

TRACE CONSTITUENTS IN PPM: HYDROGEN = 893/
OXYGEN = 906/ARGON = 257/PUMP OIL = 23/
"FREON" = 31/

Unidentified Organic Contamination Noted

RCA CD4011A S/N 41

=====

CONSTITUENT	CONCENTRATION, % (V/V)
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HYDROGEN	.1
METHANE	.3
WATER VAPOR	5.9
NITROGEN	86.3
OXYGEN	.1
CARBON DIOXIDE	7.2

14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

=====

TRACE CONSTITUENTS IN PPM: HYDROGEN	=	751/	
OXYGEN	=	800/ARGON	= 268/PUMP OIL = 25/
"FREON"	=	33/	

Unidentified Organic Contamination Noted

RCA CD4011A S/N 49

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CONSTITUENT	CONCENTRATION, %(V/V)
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WATER VAPOR	.1
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NITROGEN	99.6
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CARBON DIOXIDE	.3
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14 LEAD HERMETIC FLAT PACK: 1/4"X3/8"

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RCA CD4011A S/N 50

=====

CONSTITUENT	CONCENTRATION, % (V/V)
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WATER VAPOR	.1
NITROGEN	99.6
CARBON DIOXIDE	.3

14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

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TRACE CONSTITUENTS IN PPM: ARGON = 16/

RCA CD4013 S/N 23

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CONSTITUENT	CONCENTRATION, % (V/V)
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NITROGEN	99.3
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CARBON DIOXIDE	.6
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14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

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TRACE CONSTITUENTS IN PPM: HYDROGEN	=	241/
WATER VAPOR = 233/OXYGEN	=	51/

03-03-77

RCA CD4013A S/N 24

=====

CONSTITUENT	CONCENTRATION, %(V/V)
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WATER VAPOR	.1
NITROGEN	99.5
CARBON DIOXIDE	.4

14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

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TRACE CONSTITUENTS IN PPM: ARGON = 52/

03-03-77

RCA CD4013A S/N 94

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CONSTITUENT	CONCENTRATION, % (U/U)
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HYDROGEN	.1
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METHANE	.2
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WATER VAPOR	4.5
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NITROGEN	88.7
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OXYGEN	.1
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CARBON DIOXIDE	6.3
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14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

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TRACE CONSTITUENTS IN PPM: HYDROGEN	=	662/	
OXYGEN	=	667/ARGON	= 262/PUMP OIL
"FREON"	=	54/	= 27/

Unidentified Organic Contamination Noted

03-03-77

RCA CD4013A S/N 95

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CONSTITUENT	CONCENTRATION, % (V/V)
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HYDROGEN	.1
METHANE	.3
WATER VAPOR	12.2
NITROGEN	76.0
ARGON	.4
CARBON DIOXIDE	10.9

14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

=====

TRACE CONSTITUENTS IN PPM: HYDROGEN = 860/
OXYGEN = 482/PUMP OIL = 32/"FREON" = 59/
Large Quantity of Organic Contamination Noted

03-03-77

RCA CD4024A S/N 19

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CONSTITUENT	CONCENTRATION, %(V/V)
-----	-----
HYDROGEN	.1
HELIUM	4.5
METHANE	.5
WATER VAPOR	16.8
NITROGEN	68.1
OXYGEN	.1
ARGON	.2
CARBON DIOXIDE	9.7

14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

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TRACE CONSTITUENTS IN PPM: OXYGEN = 635/

Large Quantity of Organic Contamination Noted

PUMP OIL = 51/"FREON" = 433/

RCA CD4024A S/N 20

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CONSTITUENT	CONCENTRATION, % (V/V)
-----	-----
HYDROGEN	.1
METHANE	.3
WATER VAPOR	11.8
NITROGEN	80.5
OXYGEN	.1
CARBON DIOXIDE	7.1

14 LEAD HERMETIC FP : 1/4" X 3/8"

=====

TRACE CONSTITUENTS IN PPM: OXYGEN	=	965/	
ARGON	=	393/PUMP OIL	=
		35/"FREON"	=
Large Quantity of Organic Contamination Noted			=

03-03-77

RCA CD4024A S/N 30

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CONSTITUENT	CONCENTRATION, % (V/V)
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HYDROGEN	.2
METHANE	.2
WATER VAPOR	12.0
NITROGEN	81.4
OXYGEN	.1
CARBON DIOXIDE	6.0

14 LEAD HERMETIC FP : 1/4" X 3/8"

=====

TRACE CONSTITUENTS IN PPM: OXYGEN	=	641/	
ARGON	=	461/PUMP OIL	= 69/"FREON" = 126/

Unidentified Organic Contamination Noted

RCA CD4024A S/N 42

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CONSTITUENT	CONCENTRATION, %(V/V)
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HYDROGEN	.1
METHANE	.3
WATER VAPOR	12.2
NITROGEN	79.5
OXYGEN	.1
CARBON DIOXIDE	7.7

14 LEAD HERMETIC FLAT PACK: 1/4" X 3/8"

=====

TRACE CONSTITUENTS IN PPM: OXYGEN	=	599/	
ARGON	=	465/PUMP OIL	= 38/"FREON" = 68/

Unidentified Organic Contamination Noted